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DEPARTMENT OF THE INTERIOR
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EXTRACTION AND USES OF LITHIUM IN GERMANY

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GEORGE T. MOTOCK

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FOREWORD

This report was prepared by the author, a technologist in the lithium industry, loaned for the investigation by Metalloy Corporation, Minneapolis, Minn. The data were obtained during a trip to Germany for the Technical Industrial Intelligence Committee (T.I.I.C.) subcommittee on Metals and Minerals during the summer of 1945. The purpose of this committee, which functions under the Joint Intelligence Committee of the Joint Chiefs of Staff of the United States Armed Forces and of which the Bureau of Mines is a member, was to obtain information of interest to American industry and of value to the United States Joint Control Council for Germany. The paper was submitted through the Joint Intelligence Objectives Agency, which succeeded T.I.I.C., and is released for publication through the Bureau of Mines in order to reach the audience that can make the best use of it. In all cases the individuals or teams sent on the investigating missions were chosen from the best-qualified men available in the industry and in the various Government agencies. The material herein was prepared entirely by the author, who is not a member of the Bureau of Mines.

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

EXTRACTION AND USES OF LITHIUM IN GERMANY[1]

By George T. Motock[2]

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LITHIUM EXTRACTION AND USES

Summary

In Germany the extraction of lithium and its salts has been handled mainly by units of the two major concerns - Metallgesellschaft A. G. and Deutsche Gold und Silber Scheide Anstalt, both with headquarters in Frankfurt.

Zinnwaldite, which belongs to the mica group, is the major source of the lithium-containing raw material in Germany. Lepidolite and amblygonite also are used when available, but they are imported, as there are no major deposits of these two minerals in Germany.

The zinnwaldite mica ore contains 0.2 to 0.5 percent lithium. This mica is concentrated by a magnetic and flotation method to 1.5 percent lithium, and the resulting concentrate is sent to the Langelsheim (Harz) plant of Metallgesellschaft, where lithium salts such as lithium chloride, lithium carbonate, and lithium hydroxide are made. Lithium metal is produced by the Rheinfelden plant of Deutsche Gold und Silber Scheide Anstalt from the lithium chloride received from the Langelsheim plant of Metallgesellschaft. The Rheinfelden plant acts only as conversion unit to produce lithium metal, which is returned to Metallgesellschaft at Langelsheim to be added to lead-base railroad bearings (Bahnmetall). The Marguardt plent at Beuel, a unit of Degussa (Deutsche Gold and Silber Scheide Anstalt), makes lithium salts from amblygonite, which is imported. Some of the lithium salts are sold to chemical companies for use in making lithium fluoride or pharmaceutical chemicals. Some of the metallic lithium has been used in copper alloys by the Vereinigte Deutsche Metallwerke, a unit of Metallgesellschaft. During the war, Germany used lithium in magnesium, but this information is not too well-verified. They might have used lithium or cerium in metal for impellers.

Research has been done on the addition of high percentages of lithium to magnesium.

Bahnmetall containing lithium is a well-established product, and at present this is the major use for lithium metal. All three plants - (1) at

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Langelsheim for making lithium salts from the lithium mica and for making Bahnmetall with lithium metal addition, (2) at Beuel for making lithium salts from amblygonite, and (3) at Rheinfelden for making lithium metal from lithium chloride - are in condition to operate immediately.

INTRODUCTION

The information contained in this report was obtained by personally visiting the offices and plants of the concerns dealing with lithium and its extraction and use.

Metallgesellschaft A. G.

The main office is at Reuterweg, Bokenheumer Anlage No. 45, Frankfurt-am-Main, Germany. This target was investigated several times in the period July 26 to September 17, 1945. The following personnel were interviewed:

H. W. Lumme, director of shipping, Frankfurt.

Rudolph Euler, president, Frankfurt.

Hans G. Heine, patents and technical, Frankfurt.

Dr. Franz Tradeus, in charge of the legal department, Frankfurt.

Dr. E. Thieler, in charge of the library and technical reports. The library is at Proworoff Strasse No. 2, Bad Homburg, near Frankfurt. Thieler lives at Franken Strasse No. 2, Bad Homburg, near Frankfurt.

Dr. Hans Oehmichen, mining engineer, Bad Homburg, near Frankfurt.

Dr. Rösner, chemist, who has all the chemical reports, Erbstadt, near Friedberg.

Dr. Helmut Kuhr, manager of the Hans Heinrich Hütte plant at the Langelsheim (Harz) unit of Metallgesellschaft.

Dr. Ludwig Schuster, technical director of Hans Heinrich Hütte plant at Langelsheim (Harz), in charge of lithium salts and Bahnmetall production.

Hubert Gerhard, superintendent of the lithium plant at Langelsheim (Harz).

Dr. Wilhelm Overath, technical director of Metallgesellschaft (Frankfurt), in charge of bonderizing and parkerizing surface treatment chemical production, works at the Hans Heinrich Hütte plant, Langelsheim, and lives at Goslar (7 km. from Langelsheim).

Details of the organization, plants, and products as well as the present location of some of the records of Metallgesellschaft are given later in this report.

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Deutsche Gold und Silber Scheide Anstalt (Degussa)

At present, the main office is at 31 Guteleutestrasse, and two plants are at 7 Weissfrauenstrasse and 215 Guteleutestrasse, all in Frankfurt.

The plant where lithium metal is produced is at Rheinfelden on the Rhein, near Basel, and the Marguardt unit for making lithium salts from amblygonite is at Beuel, near Bonn, south of Cologne (Köln).

This target was investigated several times during the period July 27 to September 18, 1945. The following persons were interviewed:

Dr. Martin, experience on lithium, office at 31 Guteleutestrasse, Frankfurt.

Dr. Leopold Harant, chief chemist, working part time at 31 Guteleutestrasse, Frankfurt, and part time at a small plant in Stierstadt, near Frankfurt, where they produce and do research work on high melting point refractories made of oxides of beryllium, aluminum, chromium, and zirconium. The plant at Stierstadt is outside the village of Oberursel, near the railroad tracks, in a group of buildings in the middle of a field (like a farm).

Dr. Gustav Jaeger, in charge of the ceramics department, which is at Stierstadt. He lives at 25 Taunusstrasse, Neu Isenburg, near Frankfurt.

Dr. Hans Medweth, in charge of the plant at Rheinfelden (he replaced Dr. Pressell, who was in charge of the lithium plant at Rheinfelden).

Ernst Brach, foreman of the beryllium unit at the Rheinfelden plant.

E. Kaufman, foreman at the Stierstadt ceramic plant.

Dr. Walter Völkel, expert on beryllium, at 215 Guteleutestrasse, Frankfurt.

Dr. Karl Bromig, in charge of pharmaceutical chemicals, at 215 Guteleutstrasse, Frankfurt.

Dr. Claviter, works manager (replaced Dr. Pfister) of Dr. L. C. Marguardt A. G. at Beuel, near Bonn, south of Köln (Cologne). The Dr. L. C. Marguardt A. G. is a unit of the Degussa group of plants.

Details of the organization, plants, products, etc., of Degussa (Deutsche Gold und Silber Scheide Anstalt) are given later in this paper.

Vereinigte Deutsche Metallwerke A. G.

(Controlled by Metallgesellschaft) located at Heddernheim, near Frankfurt am Main. Persons visited were Otto Barthel, technical director; Dr. Emil Lay, chief metallurgist; Fritz Künstel, chief of foundry; Heinrich Kraft; and J. Müller, plant superintendent.

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EXTRACTION OF LITHIUM AND LITHIUM SALTS

Raw Materials

Up to the time of the first world war, the manufacture of lithium salts in Germany was mostly in the hands of a few large chemical companies. The raw materials consisted of ores such as amblygonite from Tsumeb in Southwest Africa, which was comparatively rich in lithium (6 to 8 percent lithium oxide). A turning point in the manufacture of lithium salts was reached in 1918, when a new use for lithium was discovered in the metallurgical laboratory of the Metallgesellschaft, Frankfurt am Main. It was found by experiment that the addition of a few hundredths percent lithium gave a degree of hardness to aluminium and its alloys that could not be attained in any other way. Metallgesellschaft started in 1922 to manufacture its own supplies of lithium from the ores. For the production of lithium chloride, a lepidolite containing only about 1 percent lithium was first considered. Later on a new use for lithium was found, which was as addition to lead-base bearing alloy for railroads. This necessitated development of a larger and steadier supply of raw materials containing lithium.

This was found in the zinnwaldite contained in a tin ore occurring in the Saxonian mountains. This ore was originally mined for the extraction of tungsten and tin, and the tailings that were discarded contained 0.2 to 0.5 percent lithium; the rest was sand.

Zinnwaldite

($K(FeLi)_3(Si_3(Al_{10}(OH)_2)$) occurs in Zinnwald, Erzgebirge, near Freiberg. This ore was mined by the Stahlwerke Berker in Zinnwald for the extraction of tungsten and tin. The resulting waste was left in two very large dumps, which were taken over by the Metallgesellschaft for the extraction of lithium. In Germany, this waste is considered as lithium mica (glimmer). Zinnwaldite is considered as mica in the same group with lepidolite, except that there is partial substitution of aluminium by iron.

The concentration of this lithium-containing mass was started in 1926, first by magnetic separation on a scale up to 120 metric tons per month, enriching the lithium content to 1.3-1.4 percent. During 1931 and 1932 the concentration plant at Zinnwald was out of operation because the Hans Heinrich Hütte plant imported amblygonite (5 percent lithium) from Spain and Southwest Africa.

Up to 1941, concentration of the tailings accumulations consisted in roasting in order to make it easier to separate the iron oxides by magnetic means. Further separating is done by four cross magnetic belts, Humboldt system, the concentrate containing 1.3 to 1.4 percent lithium.

In 1941, Metallgesellschaft built a new magnetic conentration plant. In this plant the lithium-containing material is first ground, then screened and separated into sizes of 15 mm., 8-15 mm., 4-8 mm., and under 4 mm. Next, it is dried in a kiln before it is magnetically concentrated in a strong field separator made by Studiengesellschaft für Doggerze, Amberg. This

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magnetic concentration plant had a capacity of handling 2 metric tons (a metric ton is closely equivalent to a long ton) of material per hour with an output of concentrates of 5 tons per day. Later on, Krupp Gruson and Westfalia Dinnendahl-Gröppel Planungen built a flotation and magnetic unit for handling up to 150 tons per day of the lithium-containing material.

Lithium Salts Extraction from Lithium Mica (Glimmer)

The concentrate that is brough from Zinnwald to the Hans Heinrich Hütte plant at Langelsheim (Harz) contains 50-52 percent SiO_2, 10-12 percent Fe_2O_3, 19-20 percent Al_2O_3, 1.5 percent Mn_2O_3, 9 percent K_2O, and 3 percent Li_2O = 1.4 percent lithium.

Lithium Carbonate, Technical Grade

The concentrate received at Langelsheim is dried first, if it contains water, and is then mixed with potassium sulfate in the proportions 70 percent lithium mica and 30 percent K_2SO_4 and ground in a dry grinder to 100 mesh at speed of 3,000 r.p.m. The mixture is then taken by automatic elevator to a storage bin, milled, mixed again, and then roasted in a rotary kiln at 900° C. The dimensions of this rotary kiln are: Length, 10 meters (11 feet); outside diameter, 1 meter (3 feet 3 inches); and inside diameter, 0.8 meter (3 feet). It rotates once every 81 seconds, discharging 6 to 7 metric tons in 24 hours. This mixture is then mixed with 2,000 liters water for each 1,000 kg. solids and is boiled with direct steam for about 30 minutes. By this step, lithium sulfate (which is soluble) is extracted. The solution-mixture is then taken in a closed tank and sent by air pressure through the filters. The filters are washed with water, and this water, which picks up potassium salts, is returned to the mixing vat. The filter consists of 35 chambers with sodium cellulose filter cloths. It takes 20 minutes to filter a 1,000-kg. mixture.

The filtered solution contains 3.5 gr. lithium and 5.5 gr. K_2SO_4 per liter. It is then evaporated to a concentration of 8 to 9 grams lithium per liter. This strong solution is purified with sodium hydroxide to remove the manganese and iron by stirring with air, and is then passed through a 13-chamber filter.

After filtering, the hot solution is brought into a tank, where K_2SO_4 is partly crystallized by evaporation, cooled in a stirred tank to room temperature, when most of the K_2SO_4 is then crystallized. This is then separated by settling. This potassium sulfate is re-used to mix with new lithium mica concentrate. The filtrate, containing 8 to 10 grams per liter of water, is treated with an equivalent amount of potassium carbonate to form lithium carbonate, which is then dried. Other lithium salts are made from this lithium carbonate. By washing the lithium carbonate with distilled water at room temperature, traces of K_2SO_4 and chloride are eliminated.

Pharmaceutical Pure Lithium Carbonate, DAB-6 - Brit. Pharm.

Technical lithium carbonate is brought into solution with hydrochloric acid and then precipitated with sodium carbonate to get pure lithium carbonate.

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Lithium Chloride

Lithium chloride is made from pure lithium carbonate by adding 1.2 sp. gr. hydrochloric acid to lithium carbonate that contains enough water to have the consistency of paste. The lithium chloride is melted for electrolysis in producing lithium metal.

Lithium Hydroxide

The chlorine-free washed lithium carbonate is mixed with calcium hydroxide. For each batch there are taken 200 kilograms of lithium carbonate and 240 kilograms calcium hydroxide in water suspension. This is then evaporated at low pressure, filtered, and evaporated in a rubber-lined (0.1 mm.-thick) iron container to a 55 percent lithium hydroxide liquor, which can be concentrated to 98 percent by vacuum drying.

Lithium Fluoride

Lithium fluoride is not made by Metallgesellschaft. In 1942, Metallgesellschaft produced 11,637 kilograms lithium from lithium mica and 1,702 kilograms lithium amblygonite in the form of the following products:

	Kilograms	
	1942	1941
Lithium carbonate	18,987	12,130
Lithium chloride	12,630	13,725
Lithium hydroxide	40,506	38,003
Lithium metal	1,230	505

Lithium carbonate and hydroxide were sold to Merck and other chemical concerns to make medical salts and lithium fluoride. Lithium hydroxide is used for storage batteries, also. All the lithium chloride was used for making lithium metal.

Lithium Salts Extraction from Amblygonite

The Dr. Marguardt A. G. unit of Degussa (Duetsche Gold und Silber Scheide Anstalt) produces lithium salts from amblygonite imported from the United States, Spain, Southwest Africa, or Finland, and from lithium mica that they can get from the Metallgesellschaft. The amounts of lithium mica received from Metallgesellschaft were:

Year	Tons
1943	530
First half 1944 ..	293
July-Sept. 1944 ..	149

Marguardt A. G. plant in Beuel, near Bonn, produced the following lithium salts in July 1944:

	Kilograms
Lithium carbonate, technical	1,000
Lithium carbonate, pure	1,025
Lithium chloride, technical	3,140
Lithium chloride, pure	2,580
Lithium fluoride	1,373

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Process for Making Lithium Carbonate U.S.A. from Amblygonite Received from U.S.A.

This amblygonite contained about 8 percent lithium oxide. The following (1931) method is used: In decomposing this mineral with sulfuric acid, the added aluminum sulfate (15/17 percent Al_2O_3) will tie up the phosphoric acid as aluminum phosphate, thus avoiding the reformation of lithium phosphate. On a laboratory scale there has been no loss, but in the actual production there was a total loss of 13.5 percent of the lithium content, compared with earlier losses of about 20 percent.

Process

About 300 kg. of finely ground amblygonite is mixed with 130 kg. of sulfuric acid and 60 kg. of aluminium sulfate and heated for 5 hours at 750° to 800° C. The mass, which is white to red in color, is then milled and purified by the following wet method: In the equipment, built for strontium nitrate, 1,000 to 1,200 kg. of the milled mass is boiled with 3 to 4 cubic meters of water in tinned-steel tanks, the solution being stirred continuously while enough sodium carbonate (5-10 kg.) is added to take care of all dissolved aluminium. After filtering the mixture, the solution is placed in a third tank, and to it is added 30 to 50 kg. sodium carbonate to eliminate the calcium. In this solution of 10° to 12° Be, lithium carbonate is not precipitated.

This mixture is then left for 12 hours for the precipitated calcium carbonate to settle. It is then filtered, and the filtrate is concentrated by evaporation. Lithium carbonate is then precipitated with sodium carbonate and filtered. The lithium carbonate is washed with distilled water and then dried.

Lithium Carbonate from Amblygonite Imported from Spain (1932)

This process is somewhat different than the previous one. In handling the Spanish amblygonite there was no need to use aluminium sulfate. Each batch consisted of 300 kg. amblygonite (30-mesh) with 140 kg. sulfuric acid 60° Be. The resulting mass is dried and milled and packed in 100-kg. lots for the wet process. In this wet process, the equipment consists of four steel tubs (1-2-3-4) above and four vats (1-2-3-4) below and a Glauber's salt steel tank of 8 cubic meters capacity.

In tubs Nos. 2 and 3 above there will be washed 1,200 kg. of frit with hot water in each tub, allowed to settle, and then filtered into vats 2 and 3 below. From vats 2 and 3 the mixture is taken up to tubs 1 and 4 above. The undissolved mass left in tubs 2 and 3 above is washed with water, filtered, and then dried with air. The dry mass will contain 0.2 percent lithium. The wash water is used over again for new batches.

The solution in tubs 1 and 4 above is boiled with 15 kg. sodium carbonate, which is sufficient to precipitate out the calcium, iron, and aluminium, and is then filtered and concentrated to 20° Be by vacuum-evaporation. To this solution is then added concentrated solution of sodium carbonate to precipitate lithium carbonate.

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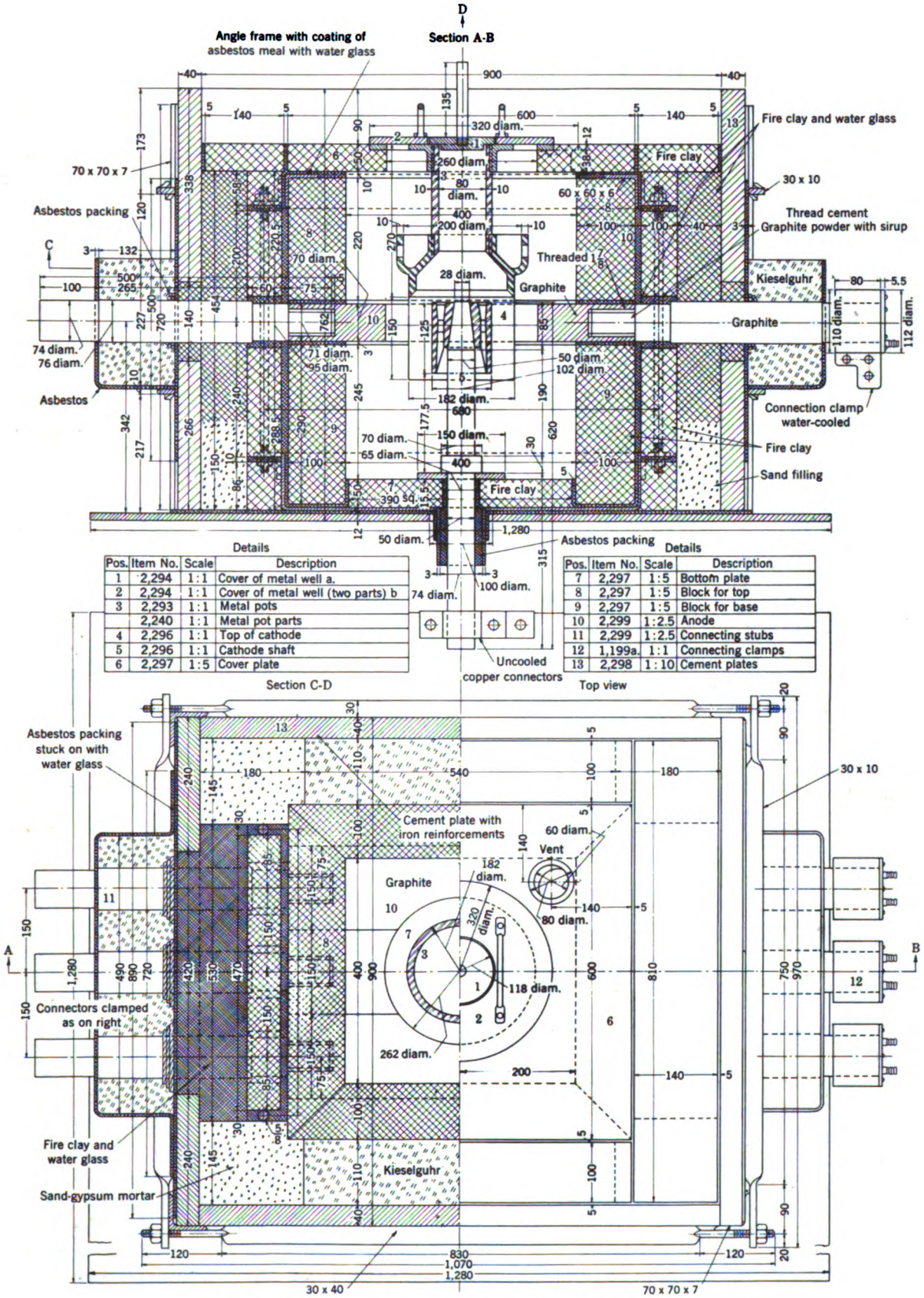

Details

Pos.	Item No.	Scale	Description
1	2,294	1:1	Cover of metal well a.
2	2,294	1:1	Cover of metal well (two parts) b
3	2,293	1:1	Metal pots
	2,240	1:1	Metal pot parts
4	2,296	1:1	Top of cathode
5	2,296	1:1	Cathode shaft
6	2,297	1:5	Cover plate

Details

Pos.	Item No.	Scale	Description
7	2,297	1:5	Bottom plate
8	2,297	1:5	Block for top
9	2,297	1:5	Block for base
10	2,299	1:2.5	Anode
11	2,299	1:2.5	Connecting stubs
12	1,199a	1:1	Connecting clamps
13	2,298	1:10	Cement plates

Figure 1.—Lithium crucible (all dimensions are in millimeters).

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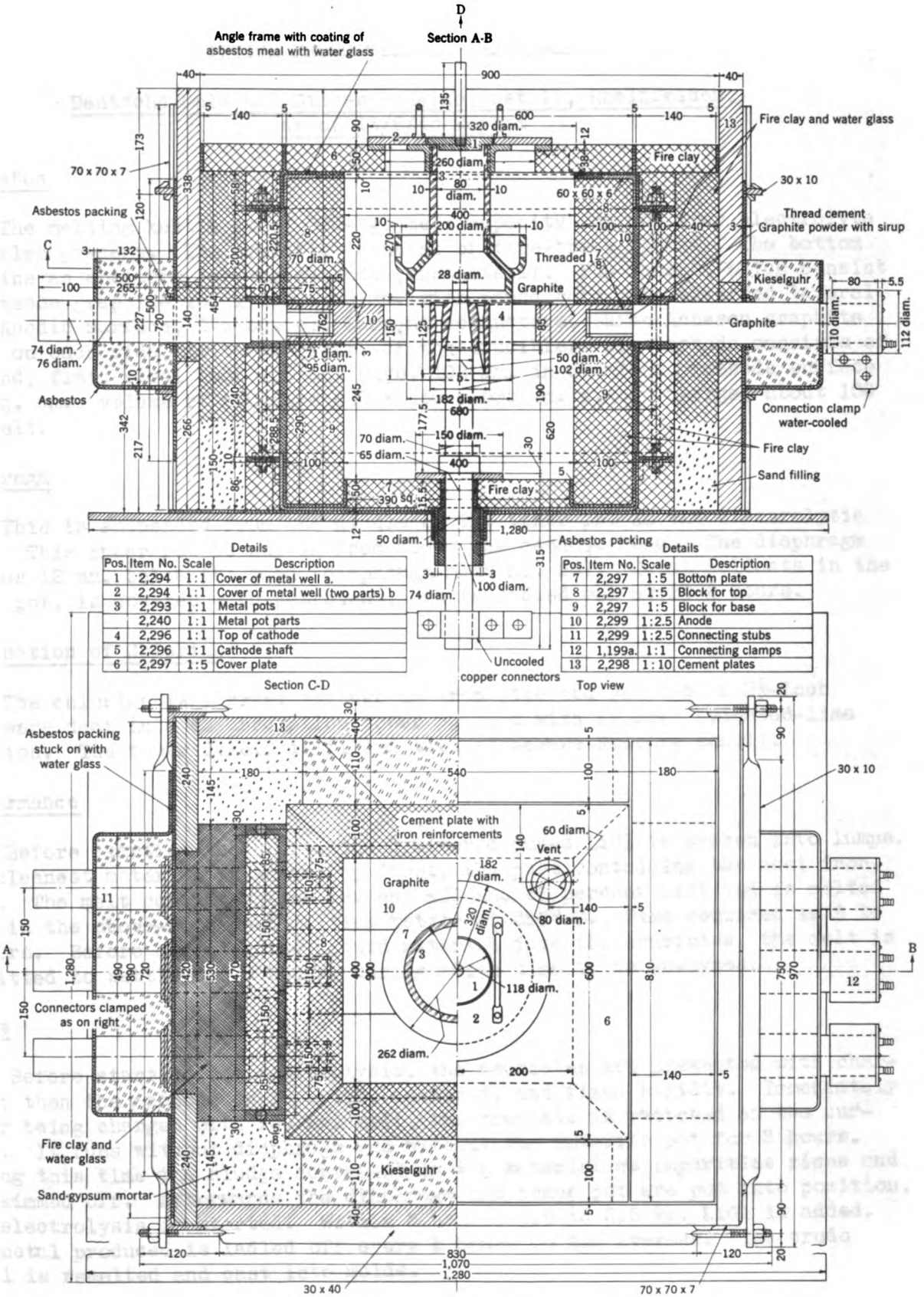

Details

Pos.	Item No.	Scale	Description
1	2,294	1:1	Cover of metal well a.
2	2,294	1:1	Cover of metal well (two parts) b
3	2,293	1:1	Metal pots
	2,240	1:1	Metal pot parts
4	2,296	1:1	Top of cathode
5	2,296	1:1	Cathode shaft
6	2,297	1:5	Cover plate

Details

Pos.	Item No.	Scale	Description
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9	2,297	1:5	Block for base
10	2,299	1:2.5	Anode
11	2,299	1:2.5	Connecting stubs
12	1,199a.	1:1	Connecting clamps
13	2,298	1:10	Cement plates

Figure 1.--Lithium crucible (all dimensions are in millimeters).

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LITHIUM PRODUCTION AT RHEINFELDEN

Deutsche Gold und Silber Scheide Anstalt, Rheinfelden, as of 13/8/45 Report

Apparatus

The melting kettle is of 500-kg. melt capacity for the four electrolyte crucibles present. The crucibles consist of fire-brick blocks. The bottom contains an aperture for the cathode (cast steel). The anodes, which consist of Acheson graphite 150 x 600 x 70 mm. with round core, are inserted laterally. Anodic surface, 576 sq. cm. Current conductors, three Acheson graphite bolts on each side, left and right, of the crucible. The cathode consists of a round, flat, steel head 125 cm. high, 102 mm. in diameter, cathode surface 400 sq. cm., volume of crucible 450 x 450 x 535 mm. high. Charge, about 100 kg. melt.

Diaphragm

This is suspended from the middle of the inner pot in the electrolytic cell. This inner pot is put in from above the cathode head. The diaphragm reaches 12 mm. below the head (diaphragm mesh No. 24). Metal collects in the inner pot, is covered with petroleum, and is ladled out every 2 hours.

Elimination of Chlorine

The chlorine is carried through an iron pipe and joint to a 2½-inch stoneware duct into an absorption tower charged with aqueous hydrated-lime solution. The tower itself is filled with stoneware Raschig annuli.

Performance

Before starting the shift, the delivered fused LiCl is broken into lumps. The cleanest material is worked up first; the part containing the most iron, last. The melt consists of 48 percent KCl and 52 percent LiCl and is melted down in the above-mentioned melting kettle at 387° C.. Time required is 6 to 7 hours. Before charging the liquid material into the crucibles, the melt is permitted to settle for 5 hours, during which time it is analyzed.

Start

Before starting the electrolysis, the crucibles are preheated with charcoal; then the cathode is inserted, centered, and fixed rigidly. Immediately after being charged with 100 kg. melt, the crucible is switched on the current. It runs without diaphragm and without the interior pot for 2 hours. During this time the sludge contained in the material as impurities rises and is skimmed off. Afterwards the diaphragm and inner pot are put into position, and electrolysis is started. Within 2 hours, 2.0 to 2.5 kg. LiCl is added. The metal produced is ladled off every 2 hours on the average. The crude metal is remelted and cast into molds.

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Operational Data of Electrolysis

Temperature of crucible is 400° to 420° C.; average amperes, 850 to 900 at 8 to 9 volts; anodic current density, 139 amp. sq.dm.; cathodic current density 200 amp. sq. dm.; current efficiency, 85 to 90 percent production, 0.220 to 0.235 g./amp.-hour, e.g. 4-5 kg. lithium per crucible/day. The crucible has a life of about 170 working days.

Elimination of Chlorine

This is carried out in a stoneware precipitation apparatus by hydrated lime, which must be changed daily. On the average, 60 to 67 kg. CaO is stirred into 1.5 cubic meters water. Exhaustion of the lime milk is indicated by the pink coloration of the water.

Diffibulties

Harmful for the yield are SO_2, SO_3, SiO_2, Ba, Ca, much K, and especially Fe_2O_3. Heavy contamination of the raw material with Na leads to a lithium metal containing a high content of sodium, which causes the easy combustibility of the lithium metal.

Remelting

The ladled crude metal was once daily remelted in an electrically heated kettle. Here and again, paraffin oil was injected to avoid the combustion of the lithium metal. The pure lithium thus obtained was cast into molds.

Consumption

Per kilogram of lithium metal, there are required about 140 kw.-hr. electrical power, 7.3 kg. LiCl, and 0.3 kg. KCl.

Capacity

Six crucibles at 4.5 kg. produce a maximum 800 kg. per month.

Electrolysis

The source of power consists of 1 Langbein-Pfanhauser dynamo of 1,100 amps. and 25 volts.

Control

Crude material: Each drum is tested analytically for content of LiCl and total chlorine as well as impurities. From the bulk of drums of one campaign, the average of NaCl, KCl, Fe_2O_3, Al_2O_3, SiO_2, MgO, BaO, CaO, SO_4, and S was calculated.

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Melt

The melt in each crucible is tested once weekly for LiCl and KCl. Based upon the data of the analysis, the melt is readjusted. The lithium metal is tested for its content once fortnightly.

Quality

The crude material in the past contained 94 to 98 percent LiCl, 2.5 percent KCl, $1\frac{1}{2}$ percent NaCl, and 0.5 percent Fe_2O_3, the latter sometimes increasing to 10 percent. The KCl used in the operation should be conveniently of 99 percent purity and contain no special contaminations.

Lithium Metal (Pure)

This contained, on the average, 97 percent Li, 1.3 percent K, and 1.4 percent Na.

Package.

(a) Galvanized drums of sheet metal, 160 mm., 220 mm. high = 2 kg. drums.

(b) Galvanized drums of sheet metal, 65 mm., 220 or 85 mm. high.

(c) For 150 g. packing: Box 65 mm. and 135 mm. height.

Type I: 2 kg.

II: 270 gm.

III: 100 gm.

IV: 500 gm.

V: 150 gm.

Methods of chemical analysis of lithium metal are described later in this report.

USES

Lithium metal has been used as an alloying and purifying element added to nonferrous metals. It was used in copper alloys by Vereinigte Deutsche Metallwerke (unit of Metallgesellschaft) at Heddeinheim, near Frankfurt. It was added as master copper alloy containing 4 percent lithium for the purpose of degasifying high-conductivity copper. The equivalent amount of lithium added was 0.004 percent and the residual lithium in copper was 0.002 percent. Copper-lithium master alloy was made by attaching lithium metal to a rod, which was then plunged into the molten copper.

Vereinigte Deutsche Metallwerke began to use lithium in copper in 1934, but in 1941 only 20 tons of lithium-treated copper was produced. This was

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sold as billets to F. A. Lange of Aue, Saxony, for use in making rods. Some attempts have been made to use lithium in radio tubes in order to degasify the tube.

Lithium in silver was tried by Dr. Ernst Raub of Research Institute of Testing Materials in Omünd, near Stuttgart. He also used lithium as deoxidizer of aluminum.

Lithium cadmium and other nonferrous-metal binary alloys have been studied (1932) by Dr. G. Grube of the Kaiser Wilhelm Institute für Metall Forschung in Stuttgart.

Lithium-aluminum alloys studies were made by Metallgesellschaft in 1930.

Lithium-magnesium binary and ternary with Al and other alloys were made with high percentages of lithium with resulting considerable improvement in physical properties and changed crystal structure (work done 1930-1932).

Lithium-containing lead alloys for bearings have been made by the Metallgesellschaft since 1926. These alloys contain 0.04 percent lithium. Their name was given as BnMetall (Bahnmetall) because they have been used extensively for railroad bearings. In 1930, National Lead Co. (U.S.A.) introduced its Satco alloys containing 0 to 0.06 percent lithium.

At the Hans Heinrich Hütte (unit of Metallgesellschaft) in Langelsheim, the process for making the lithium-lead alloy (Bahn-metall) is as follows:

1. Pure molten lead is mixed with calcium carbide in the proportion 8 tons lead and 500 kilograms calcium carbide and the mixture is heated to 750° C. By this step lead picks up 2 to 3 percent calcium. The kettle is heated by four oil burners - two near the top and two near the bottom.

2. From this kettle the calcium-lead alloy is poured into another (lower level) kettle, where 150 kilograms of calcium carbide are added. By this step the calcium content of the alloy is brought up to 4.5 percent calcium. While the calcium carbide is being added to the lead, the kettle is rotated and at the same time the metal is stirred mechanically.

3. This master alloy is then cast in a mold while being sprayed with water.

4. The master alloy is then melted in another kettle, and 0.04 percent lithium metal and 0.8 percent sodium are added. The final product, which has the following analysis, is cast in molds: Bahnmetall analysis: 0.7 percent Ca, 0.61 percent Na, 0.038 percent Li, 0.038 percent Al, remainder Pb. In 1943, Metallgesellschaft produced 977,000 kg. of Bahnmetall.

METALLGESELLSCHAFT A. G.

The main offiee is at Reuterweg-Bokenheimer Anlage 45, Frankfurt.

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Organization within Germany

According to the last report of 1940, the Metallgesellschaft was established on May 17, 1881, in Frankfurt, for the purpose of dealing in nonferrous metals and with a capital of 2 million marks.

In 1928, this company merged with Metallbank and Metallgesellschaft A. G. It is known that Metallbank (financial organization) controls 100 percent of Metallgesellschaft and 50 percent of Degussa (Deutsche Gold und Silber Scheide Anstalt).

Products

1. Nonferrous metals. Aluminum, antimony, lead, cadmium, copper, lithium, nickel, tellurium, bismuth, zinc, tin.

2. Alloys. Lead-base bearing metals; zinc alloys, Zamak; copper alloys with phosphorus, manganese, brass, bronze, lead-calcium, lithium (Bahn-Metall).

3. Raw materials. Ores of antimony, lead, chromium, copper, zinc, tin, scarce metals, zinc oxide, zinc dust, bauxite, barite, iron, pyrites, scrap; special products: phosphorus, phosphoric acid, sulfuric acid, arsenic acid, paints, copper sulfate, lithium salts, and other chemical products.

4. Patents and controlled processes for zinc alloys (Zamak), lead alloys (Bahnmetall), lithium metal and lithium pre-alloys (master alloys), bonderizing and parkerizing processes.

Works Plants and Companies in the Metallgesellschaft A. G.

1. Aluminum Werk G.m.b.H. Bitterfeld.

Founded in 1926 with a capital of 50,000 R.Marks; 50 percent owned; for aluminum production.

2. "Berzelius" Metallhutten G.m.b.H., Duisberg.

Founded in 1926; capital, 100,000 R.Marks; works at Duisberg, Manheim, zinc, tin and cadmium, sulfuric acid; 100 percent owned.

3. Blei- und Silberhütte Braubach G.m.C.H.

Braubach (unit of "Berzelius") on Rhein, founded in 1896; capital R.M.-5,000; lead and silver production; 100 percent owned.

4. Kautschuk-Gesellschaft m.C.H., Frankfurt.

Founded in 1926; capital, R.M. 250,000; materials for rubber industries; 100 percent owned.

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5. Lurgi Gesellschaft für Chemie und Hüttenwesen M.b.H., Frankfurt a/M.

Founded in 1921; capital, R.M. 50,000; construction and design of equipment and plants for metallurgical and chemical industries; 100 percent owned.

6. Lurgi Gesellschaft für Wärmetechnik M.b.H., Frankfurt.

Founded in 1922; capital, R.M. 25,000; construction and design of equipment and plants for mining, chemical and food industries; 100 percent owned.

7. Lurgi Apparatebau-Gesellschaft, M.b.H., Frankfurt A/M.

Founded in 1919; capital, R.M. 100,000; Cottrell-Siemens- Lurgi process and Dauer Electrode (Söderberg Electrode) process; 100 percent owned.

8. Lurgi Wertsätten G.M.b.H., Frankfurt A/M.

Founded, May 1928; capital, R.M. 20,000; special apparatus; 100 percent owned.

9. Silumin-Gesellschaft M.b.H., Frankfurt.

Founded in 1937; capital, R.M. 50,000; silumin alloys (aluminum-silicon); 50 percent owned.

With Metallgesellschaft there are associated 27 other companies in Germany partly or completely owned by the Metallgesellschaft.

"DEGUSSA" (DEUTSCHE GOLD UND SILBER SCHEIDE ANSTALT VORMALS "ROESLER"

As of May 1945, this company's works, plants, companies controlled, and products are as follows:

Registered office: Weissfrauenstrasse 9, Frankfurt (Main).

Branches: Berlin, Hamburg, Hanau, Pforzheim, Wien.

Established January 28, 1873, with a capital of M 1,200,000. By 1914 the capital was increased to M 20,000,000, and after the war of 1914/18 up to RM 76,500,000.

Objects: Refining of precious metals and production of wires, sheets, and alloys of precious metals, dental golds and other filling materials, salts of precious metals, lithium and beryllium, dental instruments, elastic stop shafts and hoses, chemicals for the production of pharmaceuticals, chemicals for treatment of food and food supply, metallic sodium, sodium peroxide and other oxygen salts, hydrogen peroxide, chemicals for washing and cleaning preparations including soap, carbon black, and lamp black; a

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great number of products of the carbonization of wood (i.e. charcoal, acetic acid, acetaldehyde, acetone, formaldehyde, hexamethylentetramine, tar oil); carbide, acetylene; salts of cyanide, means and chemicals for the destruction of noxious vermin; Durferrit salts for case-hardening and annealing; high-temperature furnaces and implements resistant to highest temperature; furnaces for case-hardening and tempering; ceramic products (on basis of precious and base metal-oxides); muffle and crucible furnaces, and implements for assaying.

Besides the production of these materials, Degussa deals extensively in precious metals and chemicals. A banking department is at the disposal of Degussa.

Description of Plants

1. Frankfurt (Main):

(a) Weisfrauenstrasse 9: Refinery, production of ceramic products containing precious metals and of salts of precious metals.

(b) Guteleutestrasse 215: Production of chemicals for the production of pharmaceuticals, the treatment of food, and food supply; cyanide salts; ceramics; refractory furneces; highest-temperature implements; casehardening, annealing, and tempering salts; hardening salts for steel, high-speed steel, and light metals; hardening and tempering furnaces of all sorts; hardening equipments, beryllium salts and beryllium metal by electrolysis.

2. Berlin-Reinickendorf: Production of wires and sheets of precious metals, dental instruments and equipments, elastic stop shafts, and hoses.

3. Hanau: Production of platinum alloys, utensils for laboratories, network catalisators, contact masses, spinning nozzles, rivets, contacts, platinum and platinum metal salts, apparatus of silver, silver solders, and alloys of precious metals for all purposes, thermoelectric pyrometers, furnaces for the industry.

4. Pforzheim: Production of alloys of precious metals, dental golds and filling materials for dental purposes.

5. Dossenheim: Production of fountain pens.

6. Rheinfelden: Production of sodium peroxide, hydrogen peroxide, sodium perborate, and other salts, i.e., for washing and cleaning purposes, for the production of soap, etc. Metallic lithium and beryllium by electrolysis.

7. Knapsack (Kreis Koeln): Production of sodium and chlorine.

8. August Wegelin, Kalscheuren (Kreis Koeln): Manufacture of carbon black and lamp black of all sorts and black colors.

9. Carl Hisgen, Worms: Production of lamp black.

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10. Bodenfelde: (See No. 27.)

11. Brilon-Wald.

12. Bruchhausen (Westfalen).

13. Bruecken (Birkenfeld).

14. Frankfurt (Oder).

15. Greifenhagen (Pommern).

16. Heinowka.

17. Konstanz.

18. Kredenbach.

19. Lorch (Rhein).

20. Mainz-Mombach.

21. Oeventrop (Westfalen).

22. Ratibor.

23. Schleiden (Eifel).

24. Vosswalde.

25. Warthenau.

26. Wildau.

27. Zueschen (Kreis Brilon).

Plants Nos. 10 to 27 are mainly producing charcoal, activated carbon, tar oil, creosote, pitch, wood lime, wood, alcohol, acetic acid, acetone, sodium acetate, methanol, solvents, formaldehyde, paraformaldehyde, hexamethylenetetramine, and amyl preparations.

28. Carbidfabrik Wyhlen: Produces calcium carbide.

29. Sales departments: Breslau, Dortmund, Dresden, Duesseldorf, Elberfeld, Essen, Köln, Leipzig, Mannheim, Muenchen, Nuernberg, Teplitz-Schoenau: Offices for the sale of precious metals and alloys thereof, dental golds and filling materials, and dental instruments.

30. Stierstadt, near Frankfurt. Ceramics. Al_2O_3, ZrO, BeO, MgO, Dr. Jaeger, in charge, lives at 25 Taunesstrasse, Neu Beuburg, near Frankfurt.

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Principal Companies Controlled Directly or Indirectly

Works-group Wolfgang; consisting of:

1. Deutsche Kunstlederwerke Wolfgang G.m.b.H., Wolfgang

Capital, 1,150,000; participation, 100 percent.

2. Atlas Ago Chemische Fabrik A. G., Moelkau (bei Leipzig).

Capital, RM 1,150,000; participation, 100 percent.

3. Wachs- und Ledertuchfabrik Treuen G.m.b.H., Treuen (im Vogtland).

Capital, RM 200,000; participation, 100 percent. Plants in Wolfgang, Moelkau, and Treuen. Production of artificial leather and similar artificial products, of chemical technical preparations, especially for the manufacture of shoes, production of nitro varnishes and adhesives, production and sale of waxed cloth and American cloth.

4. Chemische Werke Carbon G.m.b.H., Frankfurt (Main).

Capital, RM 3,000; owner of Ratibor plant (see No. 22, above); participation, 100 percent

5. Chemische Fabrik Vosswalde G.m.b,H., Frankfurt (Main).

Capital, RM 150,000; owner of Voesswalde plant (see No. 24 above); participation, 100 percent.

6. Holzhohlen-Verkaufsstelle G.m.b.H., Frankfurt (Main).

Capital, RM 20,000; sale of charcoal and products made thereof; participation, 100 percent.

7. Dr. L. C. Marguardt A. G., Bouel.

Capital, RM 1,040,000; manufacture of chemical, chemical-pharmaceutical, chemical-metallurgical, and chemical-technical products; participation, 100 percent. Makes lithium salts from amblygonite.

8. Hydrocarbon-Gesellschaft für Chemische Produkte m.b.H., Berlin.

Production of and trade with carbon black made of acetylene; participation, 100 percent.

9. Chemische Werke Fuerstenwalde, Dr. B. Hecker & Zeidler, G.m.b.H., Fuerstenwalde.

Capital, RM 288,000; production of and trade with chemicals; participation, 100 percent.

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10. Hamburger Chemikalien-Handelsgesellschaft m.b.H.

Hamburg. Capital, RM 20,000; trade with products of all kinds, especially with preparations of the chemical industry; participation, 100 percent.

11. Oesterreichische Hiag-Werke G.m.b.H. Wien

Capital, RM 1,800,000; production of chemical preparations; participation, 100 percent.

12. Bantlinische Chemische Fabriken A. G. Perecseny.

Capital, P(eng6) 500,000; production of wood alcohol, wood lime, acetone, acetone oils, and charcoal; participation 100 percent.

13. Auergesellschaft A. G., Berlin.

Capital, RM 11,000,000; production and sale of incandescent mantles, self-protecting respiratory equipments, gas masks, objects for the metal industry, in the field of lighting and heating, technical products of all sorts, pharmaceutical products; participation, 100 percent.

14. Degussa Keramisch-Chemische Werke G.m.b.H., Prag.

Capital, RM 50,000; production and sale of chemical and technical preparations of all kinds, including precious metals and preparations of precious metals; participation, 92 percent.

15. Chemische Fabrik Grünau A. G., Berlin-Gruenau.

Capital, RM 4,000,000; production of semifinished products of the tar industry, chemicals for textile and leather industry, chemicals for the enamel, glass, building, and photographic industry, technical and pharmaceutical preparations of various kind and for different purposes; participation, 86.4 percent.

16. Keramisch-Chemische Werke A. G., Prosetitz bei Teplitz.

Capital, RM 120,000; production of and trade with ceramic colours and chemical and technical preparations of all kind; participation, 58.3 percent.

17. Chemische Fabrik Wesseling A. G., Wesseling (Kreis Koeln).

Capital, RM 1,620,000; production and sale of chemical products and preparations, i.e. prussiate and prussiate blues, sulfuric acid, means for killing vermin; participation, 51 percent.

18. Oesterreichische Chemische Werke G.m.b.H., Wien.

Capital, RM 2,800,000; production of hydrogen peroxide and other chemical preparations; participation, 46.8 percent.

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19. Deutsche Gesellschaft für Schädlingsbekampfung m.b.H., Frankfurt (Main).

Capital, RM 100,000; production and sale of means for destruction of noxious vermin and the like; participation, 42.5 percent.

CHEMICAL ANALYSIS INSTRUCTIONS FOR THE LITHIUM PLANT

I. Analysis of LiCl

SiO_2

Forty g. LiCl are taken up in a porcelain dish with a little water and a few cc. of concentrated HCl and evaporated to dryness in a Finkener tower for the separation of SiO_2. After wetting with a little concentrated HCl, it is roasted for some hours to 160° C. in an aluminum drying chamber. The contents of the dish is then wetted again with concentrated HCl, dissolved in water, and poured into a beaker. The latter is placed for 12 hours on a heating plate (about 80° C.) and the precipitate is filtered off. The filter residue is incinerated in a platinum crucible wetted with a few drops of dilute H_2SO_4 (5N), ignited, and weighed. Following fluorination and estimation of SiO_2 from the difference,

Calculation: Weight times 2.5 = percent SiO_2.

If a larger residue remains after fluorination, it is necessary to fuse with Na-K-carbonate. The fusion product is dissolved in water and added to the hydrochloric filtrate from the SiO_2 estimation, which has been filled up to 500 cc. and made up into two equal parts of H_2S-metals; H_2S is led into the first part and filtered, after having been allowed to settle for several hours, ignited, and the filter incinerated with its contents in a porcelain crucible. The residue from ignition is weighed and specified as H_2S-metals.

Calculation: Weight times 5 = percent H_2S metals.

Al_2O_3

In the filtrate from the H_2S precipitation the H_2S is boiled off. Iron and aluminum are oxidized by hydrogen peroxide and precipitated with ammonia in the usual way as Fe and Al oxides.

Fe_2O_3

In the second part of the hydrochloric filtrate from the SiO_2 estimation, iron and aluminum, too, are oxidized by H_2O_2, precipitated with NH_4OH as hydroxides, and filtered off. The filter residue is dissolved in dilute HCl, and the iron in the solution is estimated iodometrically.

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Calculation cc. 1/100 N,

$Na_2S_2O_3$ times 0.000798

(log. 90222) X 5 = percent Fe_2O_3

Weight of $Fe_2O_3 \div Al_2O_3$ X 5 = percent $Fe_2O_3 \div Al_2O_3$

$$\frac{- Fe_2O_3}{= \text{percent } Al_2O_3}$$

CaO

The Ca is precipitated in the filtrate from the Fe and Al precipitation (first part of the hydrochloric SiO_2 filtrate) by ammonium oxalate and determined in the usual way.

Calculation: Weighed CaO X 5 = percent CaO

BaO

The filtrate from the Ca precipitate is acidified with HCl, and barium is precipitated as sulfate in the usual way.

Calculation: Weighed BaSO 0.6570 (log 81754)
X 5 = percent BaO.

SO_4

The filtrate from the Fe precipitation (second part of the hydrochloric SiO_2 filtrate) is acidified with HCl, and the SO_4 is precipitated and estimated in the usual way by $BaCl_2$ solution.

Calculation: Weighed $BaSO_4$ 0.4114 (log 61430)
X 5 = percent SO_4.

Cl

Another 15 g. LiCl are dissolved in water and filled up to 500 cc., filtered from the insolubles, and the chlorine titrated by 1/10 n $AgNO_3$ solution in 5 cc. of the solution.

Calculation: Used up cc. 1/10 n $AgNO_3$ solution
X 0.003546 (log 54974) $\frac{100}{0.15}$ = percent Cl

LiCl

For the separation of Li, K, and Na, 5 cc. of the solution prepared for the estimation of Cl (15 g. in 500 cc.) are evaporated in an Erlenmeyer flash to syrupy consistence, 5 cc. amyl alcohol are added, and the water is evaporated out of the mixture by blowing dry air at 110° through it. The residue is filtered through asbestos, the filter residue is dissolved in a few drops

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of dilute HCl, 4 cc. alcohol is added, and again dry air is blown through at 110°. When the water is evaporated, the alcohol is poured through the asbestos filter, and the flask is rinsed with 2 cc. amyl alcohol (anhydrous) in 3 to 4 parts. The amyl alcoholic solution is rinsed out of the suction flask with ethyl alcohol and is evaporated in a platinum crucible. The residue is dissolved in dilute H_2SO_4, fumed off, ignited until smelting, and weighed as Li_2SO_4.

Calculation: Weighed Li_2SO_4 x 0.1263 (log 10123)
$$\frac{100}{0.15} = \text{percent Li.}$$

KCl

The residue on the asbestos filter is dissolved in ethyl alcohol and water and is carried into a porcelain dish. Two cc. of $PtCl_4$ solution (5 g. $PtCl_4$ in 100 cc. H_2O) are added and concentrated on the water bath until the mass solidifies on cooling. The residue is taken up by absolute ethyl alcohol and brought onto a filter. The K_2PtCl_6 on the filter is dissolved by hot water into a weighed platinum crucible and weighed after drying at 105° C. If decomposition starts, some dilute H_2SO_4 is added, fumed off, ignited, and weighed as $K_2SO_4 \div Pt$.

Calculation: Weighed K_2PtCl_6 0.3056 (log 45515)
$$\frac{100}{0.15} = \text{percent KCl.}$$

Weighed ($K_2SO_4 \div Pt$) 0.4036 (log 60596)
$$\frac{100}{0.15} = \text{percent KCl.}$$

NaCl

The alcoholic filtrate from the K-precipitate, after adding dilute H_2SO_4, is evaporated and the platinum made insoluble by ignition. After elimination of the latter by filtration, the solution contains only Na_2SO_4, which is weighed after evaporation and ignition in the Pt crucible.

Calculation: Weighed Na_2SO_4 x 0.8230 (log 91539)
$$\frac{100}{0.15} = \text{percent NaCl.}$$

If the sample contains considerable quantities of Ca, the latter is still present in the last-mentioned solution and must be eliminated with ammonium oxalate prior to estimation of the sodium.

If other impurities besides Na, K, and Ca are present in larger quantities, they must be removed by aqueous baryta before the alkalies are separated. The barium then is removed by cautiously adding dilute sulfuric acid.

MgO

Four hundred cc. of the aqueous LiCl solution, used for the estimation of Li, Cl, KCl, and NaCl, are used for the estimation for magnesium. The

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clear solution, when boiling, is precipitated by baryta water. After sedimentation, the solids are filtered and washed with sufficient hot water and the filter residue is them dissolved with hot dilute HCl. This solution is boiled with H_2SO_4 to remove the barium. Fe_2O_3 and Al_2O_3, too, are precipitated by ammonia, and the magnesium in the filtrate is estimated as usual.

Calculation: Weighed $Mg_2P_2O_7$ x 0.3621 (log 55879)

$$\frac{100}{12} = \text{percent MgO}$$

"Crucible" Electrolyte Test of the Lithium Plant (Rapid Estimation)

Fifteen g. melt are dissolved in a measured flask in distilled water and filled to 500 cc.

I. Estimation of lithium: 5 cc. of this solution = 0.15 g. substance are added in a porcelain dish to 6 to 7 cc. of clear solution of secondary sodium phosphate containing 7.6 g. $Na_2HPO_4.12H_2O$ in 100 cc. water and evaporated to dryness on the water bath.

Twenty-five cc. cold dilute ammonia (1 : 4) are poured in several parts over the residue after it has cooled, stirring after each addition; the soluble is filtered off and washed with the remaining ammonia.

All the lithium phosphate is collected in a Gooch crucible and dried at 105° C.

Factors for calculation: Found Li_3PO_4; wanted LiCl; factor 1.098; (log 04056)

II. K-estimation: 5 cc. of the solution are required for the estimation of chlorine, according to Volhard. Total chlorine is calculated from it.

1 cc. n/10 $AgNO_3$ yields 0.003546 g. Cl.

From the calculated total chlorine less the lithium-bound chlorine (conversion factor of LiCl to Cl is 0.83630, log 92236), the content of KCl is found by multiplication by 2.103 (log 32 281); therefore,

total chlorine - LiCl.0.8363) 2.103 = KCl

(The direct estimation of K by perchloric acid was abandoned, owing to frequent explosions.)

III. Analysis of lithium metal: About 10.0 g. metal are disintegrated and dissolved in a platinum dish by 96 percent alcohol, and, when the reaction begins to slacken, by addition of distilled water (ratio of water to alcohol 1 : 1). The solution is filled up with water to 2 liters.

From this original solution a diluted solution is prepared by adding 200 cc. (= 1g metal) to 800 cc. water.

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In this dilution are estimated:

(a) Total alkali by titration of 100 cc. with n/2 HCl (methyl orange).

(b) Lithium, potassium, sodium: In 25 cc. after having evaporated the alcohol, driven off the ammonia (from LiN_3), and added some surplus HCl, as usual, by separation with amyl alcohol (see LiCl analysis).

In the original solution, however, are estimated:

SiO_2, heavy metal, iron, Al, Ca, Mg, Ba in 400 cc. = 2 g. weighed in metal.

SiO_2 is separated and estimated by evaporation with HCl resolution in little surplus HCl and water, filtering, and fluorination, as detailed described under LiCl.

The filtrate is filled up to 1,000 cc., and in 500 cc. of this solution are determined: Heavy metals by precipitation with H_2S; iron and aluminum by precipitation with ammonia; calcium by precipitation with ammonium oxalate, as usual; and barium is estimated in a separate test.

In the second 500 cc. of the hydrochloric solution is estimated magnesium by precipitation with a little baryta water, resolution of the precipitate by little HCl, repeated precipitation with baryta, removal of the surplus baryta by sulfuric acid, precipitation of the filtrate by ammonia, and filtration of the precipitate consisting of $Fe_2O_3 + Al_2O_3$. Iron is titrated in the solution iodometrically, and the filtrate is precipitated by sodium phosphate and ammonia to find magnesium.

Nitrogen is determined in a separate sample of about 10 g. metal. The sample is brought from the plant in a well-stoppered weighing glass and is conveyed in the laboratory in a Kjeldahl flask filled with CO_2 and provided with a receiver containing n/2 HCl. The solution of the metal is performed first by cautiously running in absolute alcohol, in view of the violent reaction, and, later on, distilled alcohol. After solution, the contents are distilled as usual. The weighing glass is reweighed.

Calculation: 1 cc. n/2 HCl = 0.007004 g. N =
0.0.7414 g. Li_3N log = 84535 log = 24080

IV. Lithium nitride analysis: Sometimes the lithium metal has largely been converted to lithium nitride. This can be recognized by the hardness of the metal and by the sparks that form annoyingly at disintegration.

The analysis of such material required special weighing for estimation of the nitrogen as ammonia. 0.5 g. or more, according to the degree of disintegration, are dissolved in a flask adapted for distillation of ammonia (receiver with n/2 HCl, a.s.o.) by alcohol and water, and the ammonia is distilled off.

In the ammonia-free solution the analysis can be carried out as described in the section of this report on lithium metal.

For the estimation of impurities, however, a solution is prepared as described under Li-metal, and the ammonia and alcohol are eliminated by boiling off.

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